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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY
ANNUAL REPORT

January 1996 - December 1996

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 23nd year of station operation (January 1996 to December 1996).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 23 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the I. E. S. Utilities, Inc. (formally Iowa Electric Light and Power Company), is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1658 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-25]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical, chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters Measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved, and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (fecal and E. coli)

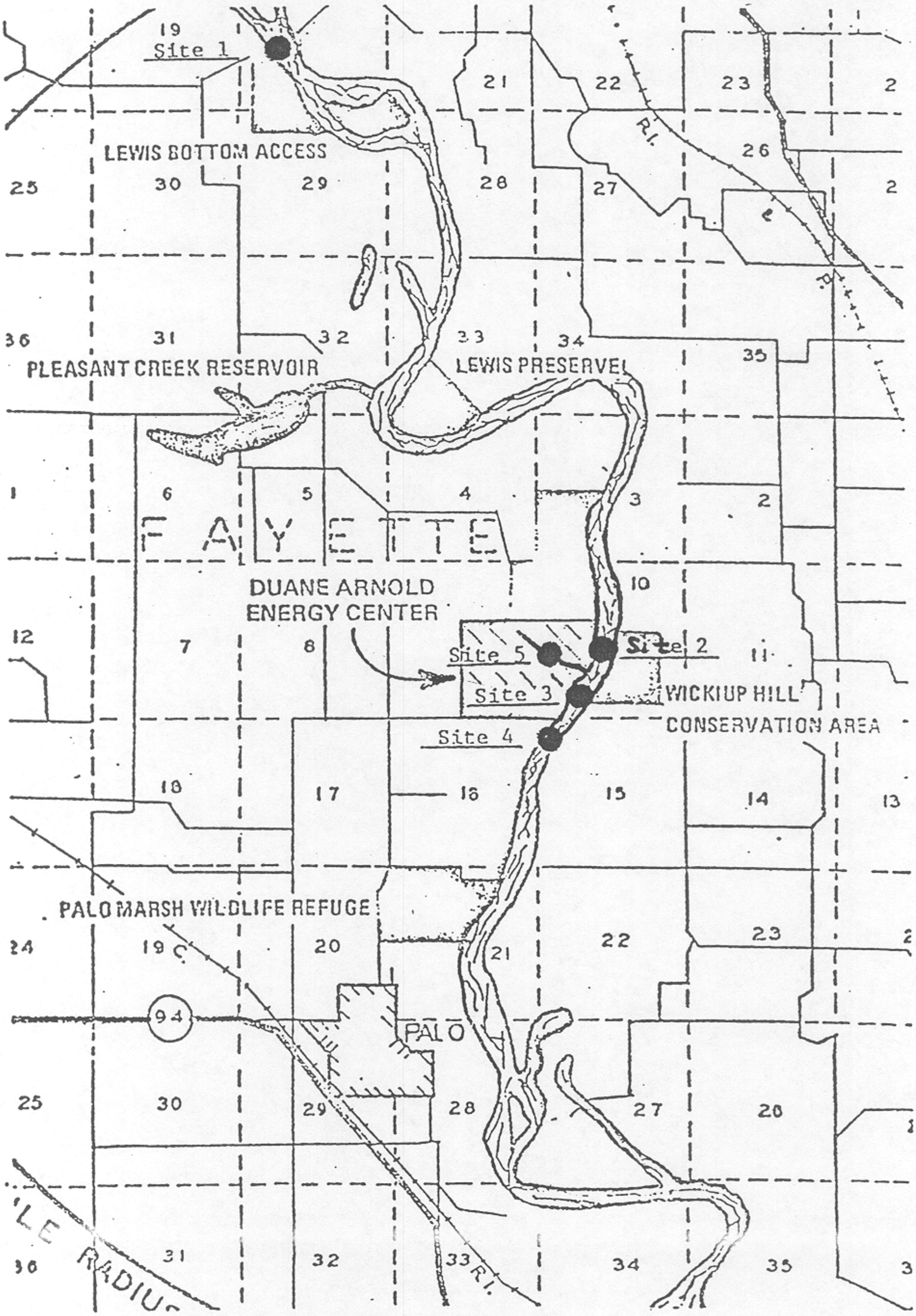

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly (April and July)

B. Locations: at all five stations

C. Parameters Measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic Studies:

1. Frequency: summer and fall
2. Location: at all five stations

B. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

C. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: three times yearly (May, June and September)
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

River flows during 1996 were lower than those present in 1995. Estimated mean flow for 1996 was 3200 cfs, substantially less than the average flow of 5237 cfs and the sixth lowest observed during the 25 years of the Cedar River water quality study. Mean monthly discharge at the U.S. Geological Survey gauging station in Cedar Rapids ranged from 1330 cfs in October to 8653 cfs in June. Flows were in excess of the 1961-1990 monthly median discharges in January, February, June, November and December. Lowest daily river flows occurred in February. A low flow of 640 cfs was reported on February 2 while a maximum daily river discharge of 11,200 cfs occurred in late June. River flows were relatively stable in January ranging from ca. 1000 to 1500 cfs. Flows fell to a yearly low in early February but increased to 5000 cfs by the end of the month. Flows were generally low in March and April ranging from ca. 2300 to 7000 cfs. Discharge generally increased in May to 8940 cfs towards the end of the month. A peak flow of 11,200 cfs occurred on June 23 and 24. Flows declined steadily from early July through mid-August ranging from 7000 to 1560 cfs. Discharge continued to decline through mid-September falling to 1020 cfs by September 19. October flows were low but increased to 2700 cfs by the end of the month. Flows generally declined through mid-November to ca. 1700 cfs and then increased, remaining in excess of 2500 cfs through December. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient upstream river temperatures during 1996 ranged from 0.0°C (32.0°F) to 26.0°C (78.8°F). The maximum ambient (Station 2) temperature was observed on July 2. This value was 2.5°C (4.5°F) lower than that observed in 1995[25] but only slightly lower than the 1980 to 1995 average maximum of 26.6°C (79.9°F). A maximum downstream temperature of 26.0°C (78.8°F) was also observed at Station 3 on July 2. The highest discharge canal (Station 5) temperature observed during the period was 29.0°C (84.2°F), also recorded on July 2. The maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 11.5°C (20.7°F) was observed on April 17.

Station operation continued to have a negligible effect on downstream water temperatures. The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 2.0°C (3.6°F) was measured in mid-October. Maximum temperature elevations at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) were 1.0°C (1.8°F) in September and October. Obviously there was no instance in which a temperature elevation in excess of the Iowa water quality standard of 3.0°C[26] was observed. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values were similar to those present in 1994 and 1995 (Table 27). A peak value of 120 NTU occurred at several river locations on April 13. Low values (2-4 NTU) occurred in January and February. Turbidity values in the discharge canal were consistently higher than those observed in the upstream river. A maximum discharge canal turbidity of 880 NTU was observed on January 2.

Solids (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were somewhat lower than those observed in 1995.[25] Values ranged from 290 to 540 mg/L, with the majority falling between 300 and 400 mg/L.

Dissolved solids values were similar or slightly lower than those present in 1995. Upstream values ranged from 200 to 390 mg/L. Values of less than 250 mg/L generally occurred from mid-July through October. High values continued to occur in the winter. As in most previous years, dissolved solids values at Station 3 and 4, downstream of the discharge canal, were slightly higher than values observed upstream. A maximum downstream value of 420 mg/L was observed at Station 3 on December 4.

Suspended solids values at river locations were generally similar to those of the previous year ranging from 1 to 200 mg/L. Low values occurred in January, February and December while highest values occurred during April and June.

As in previous years, total and dissolved solids values in the discharge canal were much higher than in the river samples. Maximum total solids concentrations of 3400 mg/L were observed in the discharge canal in January while a minimum value of 290 mg/L was observed in October when the station was off line. Most total solids values in the discharge canal were in excess of 1200 mg/L. Dissolved solids levels in the discharge canal ranged from 240 mg/L in October to 2100 mg/L in early July. Suspended solids values in the discharge canal also continued to be consistently higher than those present at river locations but differences were not as apparent as they were in the case of total or dissolved solids.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1996 ranged from 8.0 to 16.2 mg/L (88 to 171% saturation). High dissolved oxygen concentrations (ca. 11-13 mg/L) continued to occur in the river in winter when temperatures were low and the solubility of the gas was highest. In addition supersaturated oxygen values were frequently observed in the late summer and autumn in conjunction with algal photosynthesis. Lowest dissolved oxygen values occurred in June and early July.

Dissolved oxygen concentrations in the discharge canal (Station 5) were usually lower than those present at river locations ranging from 1.7 to 13.8 mg/L (21 to 100% saturation). The highest dissolved oxygen concentration occurred on November 20 when the station was off line. The lower dissolved oxygen concentrations in the discharge canal did not impact downstream levels.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations in river samples were somewhat higher than those present in 1995, ranging from <1 to 24 mg/L. Values were generally below 1 mg/L from mid-July through early October. Maximum levels (12-24 mg/L) occurred from February through early March. Values in the discharge canal could not be precisely determined but, based on pH levels, were probably higher.

Alkalinity, pH, Hardness (Tables 10-14)

These interrelated parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Total alkalinity values in the 1996 river samples were similar to or slightly lower than those present in 1995.[25] River values ranged from 92 to 252 mg/L. Lowest values occurred in mid-August and early September during a period of relatively low flow. Highest values occurred January, February and December. Total alkalinity values in the discharge canal exhibited considerable fluctuation ranging from 80 to 870 mg/L.

Carbonate alkalinity was not present in river samples from January through early April, June, November and December. A maximum value of 18 mg/L was observed in September in conjunction with increased algal activity.

Values for pH in river samples were generally higher than those observed in 1995[25], especially during the summer and autumn. Values ranged from 7.5 to 9.1 with highest values occurring in August through early October. As in previous years, highest levels accompanied increased photosynthetic activity while low values occurred in February and early March.

Total hardness values in the upstream river were somewhat lower than those present in 1995[25] and generally paralleled total alkalinity levels. The highest values (340-400 mg/L) occurred in early February while low values of 160 to 180 mg/L occurred in April and September.

Hardness values in the discharge canal continued to be consistently higher than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 230 to 1500 mg/L. Levels downstream of the station however were only slightly higher than upstream values. Lowest hardness values in the discharge canal occurred when the station was off line.

Calcium hardness values paralleled total hardness values. Concentrations ranged from 75 to 260 mg/L in the river and from 100 to 960 mg/L in the discharge canal.

<u>Phosphates</u> (Table 15 and 16)

Total phosphate concentrations in river samples were slightly higher than those present in 1995.[25] Concentrations in the river ranged from 0.1 to 0.7 mg/L. High levels occurred in February and April. Low values of 0.1 mg/L occurred in December. Levels in the discharge canal were consistently higher than those observed in the river. Discharge canal values ranged from 0.2 to 5.4 mg/L. Phosphate concentrations at downstream locations were occasionally slightly higher than upstream levels.

Orthophosphate concentrations in river samples were similar to those present in 1995 rarely exceeding 0.1 mg/L. Values ranged from <0.1 mg/L to 0.6 mg/L. Discharge canal concentrations ranged from <0.1 to 1.5 mg/L.

Ammonia (Table 17)

Ammonia concentrations in the river were generally similar to those observed in 1995[25] although maximum values were higher. Concentrations were below detection limits (<0.1 mg/L as N) from mid-April through early November. Concentrations of 0.8 to 0.9 mg/L (as N) occurred in February.

Nitrate (Table 18)

Average nitrate concentrations in the river decreased slightly over 1995 values and were well below the levels observed between 1990 and 1993 (Table 27). During the current year nitrate values in upstream river samples ranged from 0.3 to 11 mg/L (as N). Maximum levels, 11 mg/L (as N), occurred in June. Minimum levels occurred in August and September.

Nitrate concentrations were consistently higher in the discharge canal than in river samples. A maximum nitrate concentration of 42 mg/L (as N) was observed in the discharge canal on July 2. However downstream nitrate concentrations continued to be similar to upstream levels.

Iron (Table 19)

Iron concentrations in the river remained high during 1996. Concentrations in the river ranged from 0.10 to 6.0 mg/L. The maximum value was observed on April 3. Low values occurred in January and early February. As in previous years, high iron concentrations were observed in association with increased turbidity and suspended solids, indicating that most of the iron present was in suspended form rather than in solution. Iron levels were frequently higher in the discharge canal. A maximum iron value of 56 mg/L was observed in the canal on January 2 in conjunction with the suspension of sediment when dilution water was diverted into the discharge canal.

Biological Studies

Biochemical Oxygen Demand (Table 20)
Five day biochemical oxygen demand (BOD_5) values in the river were higher than those present in 1995[25] ranging from <1 to 18 mg/L and, averaging 7.0 mg/L in 1996 as compared to 4.0 mg/L in 1995 (Table 27). Highest values occurred from late July through October in conjunction with algal blooms. Lowest values of 1 mg/L or less occurred during the winter.

Coliform Organisms (Tables 21 and 22)
Coliform determinations included enumeration of fecal coliforms as well as specific determination of Escherichia coli.

Maximum river levels of fecal coliform and E. coli of 2,200 and 2,700 organisms/100 ml, respectively, were observed in November. Low values of 30 or less organisms/100 ml were usually observed in the autumn.

There were two instances when coliform concentrations at downstream locations were in excess of 200 organisms/100 ml above upstream locations. On January 2 an extremely high level of fecal coliform organisms of 11,000 organisms/100 ml was observed in the discharge canal which resulted in a downstream concentration of 950 organisms/100 ml. About 500 organisms/100 ml above upstream values. the high value appeared to be related to the suspension of sediment when a significant amount of dilution water from the river water supply pump house was diverted into the discharge canal. On November 20, during a period of high runoff, fecal coliform levels of 800 to 1000 organisms/100 ml above background were observed in the mixing zone (Station 3) but these higher levels appeared to be related to localized runoff rather than station operations. Sporadic instances of increased coliform concentrations at downstream locations were also observed in 1992, 1994 and 1995.[22,24,25]

ADDITIONAL STUDIES

In addition to the routine monthly studies a number of seasonal limnological and water quality investigations were conducted during 1996. The studies discussed here include additional chemical determinations, benthic surveys, asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys, and impingement determinations.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 17 and July 2, 1996 from all river locations and from the discharge canal and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. Concentrations of all parameters fell within the expected ranges. Chloride and sulfate levels were similar at all river locations to concentrations present in 1995.[25] on both sampling dates. Levels of the heavy metals chromium, lead, copper, zinc and mercury were at or below detection limits in all river samples. Copper concentrations of 20 to 30 ug/L were observed in the discharge canal on both sampling dates but copper concentrations in the river samples were all below the detection limit of 10 ug/L.

Zinc concentrations were at or below 20 ug/L in all river samples. Manganese values in river samples were similar to those observed in 1995 ranging from 110 to 190 ug/L.

Reconcentration of solids in the blowdown discharge resulted in increased levels of sulfates, manganese and zinc in the discharge canal in both the April and July samples. Chloride concentrations were higher in the discharge canal on April 17 but exhibited no increase in the July 2 samples. The high sulfate levels in the discharge canal on both sampling dates, 1000 and 1100 mg/L were due primary to the addition of sulfuric acid for pH control in the cooling water. The results of the additional chemical determinations are given in Table 23.

Benthic Studies

Artificial substrate samples (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal on July 17 and September 19, 1996. These substrates were collected on August 19 and October 31, 1996 following a five week period to allow for the development of a benthic community.

As in past years, the benthic communities which developed on the substrates were much larger and more diverse than those which are normally found in the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. A total of 30 taxa were identified during the two sampling periods, 27 in August and 19 in October. These included 27 species (6 orders) of insects, 1 specie of water mite, 1 annilid and 1 specie of nematode. Midge (Chironomid) and various caddisfly (Trichoptera) larvae continued to be the dominant organisms in both the August and October river samples. The numbers of organisms in the discharge canal also continued to be far lower than at the river locations. Diversity was also far lower in the discharge canal, 2 species in both August and October.

In general, there continued to be little difference in the overall composition of the benthic populations between upstream and downstream locations, although the number of organisms varied considerably. However, overall there did not appear to be major differences between upstream and downstream locations.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The discharge canal however, is not a suitable habitat for most benthic organisms. The results of the benthic studies are given in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In past years a number of power generation facilities experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam commonly occurs in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been reported on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1995 investigations.[11-25]

The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. The zebra mussel has been a major problem in water intakes in Europe for many years recently has caused significant problems at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the Asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate.

Since its introduction into the United States the zebra mussel has rapidly expanded its range. It is now found in all of the Great Lakes. In 1991, just three years after they were first found in the U.S., they were collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers.[27] The U.S. Army Corps of Engineers reports that zebra mussel populations have increased exponentially on lock and dam surfaces since their introduction into the Mississippi River in 1991[28,29] and it is apparent that the organism also has established itself throughout the Iowa reach of the Mississippi River. If the organism expands its range into the tributary streams of the Mississippi River problems with intake structures at power plants in the area are likely to occur. As a result of these concerns, studies designed to detect the presence of the zebra mussel were first instituted in 1990. No zebra mussels were found during the 1990 to 1995 studies.[20-25]

Studies to determine if Asiatic clams or zebra mussel were present in the vicinity of the Duane Arnold Energy Center were conducted in May, June and September 1996. On May 14 ponar dredge samples were taken from the Cedar River upstream and downstream of the station. In addition a visual inspection and ponar dredge sampling was carried out between the bar racks and traveling screens at the intake structure. The discharge canal was sampled with a ponar dredge and visual inspections of the cooling towers were conducted on June 4. On September 19 all of the above mentioned sites were sampled and inspected. In addition cement block substrates which had been placed near the discharge from Pleasant Creek Reservoir were examined. No Asiatic clams or zebra mussels were found at any of the sites during the May, June and September 1996 investigations.

Impingement Studies

The total number of fish impinged on the intake screens at the Duane Arnold Energy Center during 1996, as reported by Iowa Electric personnel, was significantly higher than during 1995.[25] Daily counts indicated a total of 897 fish were impinged during 1996. Highest impingement rates continued to occur during the winter and early spring period. During the months of January to March and in November and December 771 fish, or approximately 86% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred in July when only 1 fish was removed from the trash baskets. The month with the highest impingement rate was March, when 385 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

As in previous years the operation of the Duane Arnold Energy Center had little impact on the water quality of the Cedar River. The major factors influencing river water quality continued to be climatic and hydrological conditions and agricultural activities within the Cedar River basin.

During the current study period mean flow in the Cedar River was only 3200 cfs. This was the lowest mean flow present since 1989 and substantially lower then the mean flow of 5237 cfs present during the 25 year period that the Cedar River water quality has been conducted.

In spite of low flows and subsequently less dilution of the blowdown discharge, station operation had a minimal effect on downstream water temperatures. In

1996 the maximum observed temperature differential (ΔT) between ambient upstream temperatures (Station 2) and temperatures one-half mile downstream of the discharge (Station 4) was only 1°C (1.8°F). Average downstream (Station 4) temperatures during periods of station operation were only 0.2°C (0.36°F). This increase is slightly less than the average increase of 0.4°C (0.7°F) present in 1995 when river flows were substantially higher and dilution of the blowdown discharge was greater (Table 26).

Several other water quality parameters at downstream locations also exhibited minimal effects from the discharge of the Duane Arnold Energy Center. In all cases increases were minor and the levels present were not sufficiently high to adversely impact aquatic life. Parameters exhibiting downstream increases were iron which increased from an average of 1.69 mg/L at Station 2 to 1.85 at Station 4, phosphate which increased from 0.30 to 0.32 mg/L, hardness which increased from 254 to 274 mg/L and dissolved solids which increased from 287 to 308 mg/L (Table 26). These minor increases are comparable to values observed in prior year studies.

As in prior years studies conducted in April and July 1996 indicated that heavy metal concentrations at downstream locations were not increased by station discharge although increased concentrations of manganese, zinc and copper were present in the discharge canal. Only sulfates which are added to the cooling towers in the form of sulphuric acid for pH control exhibited slight increases at downstream locations. In no instance however were heavy metal or sulfate concentrations at downstream locations in excess of the Iowa Water Quality standards.[26]

On two occasions during 1996, fecal coliform levels were over 200 organisms/100 ml higher at downstream locations than upstream. In November, during a period of runoff, fecal coliform levels of 800 to 1000 organisms/100 ml above upstream levels were observed in the mixing zone (Station 3) but levels in the discharge canal or at Station 4, one-half mile downstream of the discharge were not elevated indicating that these high levels were related to localized runoff rather than station operation. On January 2 extremely high fecal coliform concentrations of 11,000 organisms/100 ml were present in the discharge canal which resulted in a downstream level of ca. 500 organisms above upstream values. These high values appeared to be due to the suspension of sediment which occurred when a large volume of water from the river water supply pump was diverted into the discharge canal. Sporadic instances of increased fecal coliform levels have been observed in past studies as a result of localized runoff and suspension of sediment and it is highly unlikely that these high levels are related to contamination with sources of human waste.

In general the water quality of the Cedar River in 1996 were similar to that present in 1995. However, some minor differences were observed which appear to be due primarily to the lower river flow present during the current year. Dissolved solids and hardness levels were slightly below levels present in 1995.[25] The average upstream total hardness value of 254 mg/L was the lowest observed since 1989 when river flows were extremely low (Table 27). Supersaturated dissolved oxygen concentrations and high pH values were relatively common during the summer and fall. Because of adequate amounts of nitrogen and phosphorus resulting from runoff from agricultural land, algal blooms are common in the river during the summer and fall. The low river flows present in 1996 facilitated algal photosynthesis resulting in the supersaturated dissolved oxygen levels and high pH values observed. The relatively high biochemical oxygen demand observed during the summer and fall were also related to algal activity. In past years, high biochemical oxygen demand values sometimes accompanied spring runoff from agricultural land but this condition was not observed in 1996 or in either the 1994 or 1995 studies.[24,25] Average nitrate concentrations were the lowest observed since 1989 when river flows were extremely low (Table 27). Relative loading value for nitrate, obtained by multiplying the average annual nitrate concentration by cumulative runoff, was also the lowest observed since 1989 (Table 28). The low nitrate concentrations observed also appear to be related to lower river flow and reduced runoff in 1996.

During 1996 a total of 897 fish were impinged on the intake screens at the Duane Arnold Energy Center. This is the highest number observed since 1991 when 1,415 fish were impinged.[21] Although 1996 impingement rates were somewhat higher than those of recent years, the numbers are still extremely low considering the size and nature of the fish population present in the river and the impact of impingement on the fishery of the river continues to be insignificant. As in past years increased impingement rates occurred during the winter period and appear to be related to recirculation of warm water into the intake for deicing purposes which attracts fish into the area that are subsequently impinged.

Populations of benthic (bottom dwelling) organisms which colonized artificial substrates in the summer and fall of 1996 continued to be similar to those present in past years. Diversity was similar at all river locations both upstream and downstream of the station. The greatest number and diversity of organisms occurred at Station 3 downstream of the discharge canal in August. These studies indicated that the Cedar River in the vicinity of the Duane Arnold Energy Center is capable of supporting a diverse bentic population when adequate substrate is available. The paucity of organisms normally present in the river is due to the shifting sand bottom and lack of suitable substrate. Substrates placed in the discharge canal exhibited far lower numbers and diversity of organisms indicating that the discharge canal does not provide a suitable habitat for most benthic organisms.

No zebra mussels or Asiatic clams were detected in the vicinity of the Duane Arnold Energy Center during the 1996 studies. However, the zebra mussel has been found at several sites on the Mississippi River downstream of Dubuque, Iowa and at the Burlington Generating station at Burlington, Iowa. Although the organism has not been found in either the Iowa or Cedar Rivers at this time it is likely that the mussel may enter these streams from pleasure boats that have recently been on the Mississippi River and the possibility that zebra mussels will become established in the Iowa/Cedar River basins in the future is of serious concern.

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Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1996

Date 1996	Mean Monthly Discharge cfs	Percent of Median Discharge†
January	1525	122
February	2733	167
March	3505	58
April	3787	56
May	4380	91
June	8653	159
July	3310	78
August	1809	79
September	1344	61
October	1330	56
November	2770	112
December	3258	172

*Data obtained from U.S. Geological Survey records
†Based on 1961-1990 period.

Table 2

Temperature (°C) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	0.0	0.0	1.0	0.5	0.5
Jan-18	0.0	0.0	0.0	0.0	0.0
Feb-01	0.0	0.0	0.0	0.0	0.0
Feb-15	0.0	0.0	2.5	0.5	0.0
Mar-07	0.0	0.0	1.5	0.5	0.0
Mar-19	3.5	3.5	4.5	4.0	4.0
Apr-03	7.5	8.0	15.5	8.5	8.0
Apr-17	8.5	8.5	20.0	9.0	9.0
May-01	10.5	11.0	21.5	11.0	11.5
May-14	13.0	13.0	22.0	13.0	13.0
Jun-04	15.0	15.0	20.0	15.0	15.0
Jun-20	20.0	20.5	27.0	20.5	20.5
Jul-02	26.0	26.0	29.0	26.0	25.5
Jul-16	25.0	25.5	28.5	25.5	25.0
Aug-01	22.0	23.0	26.5	23.0	23.0
Aug-15	23.0	23.5	25.5	24.0	24.0
Sep-03	23.0	23.5	27.0	24.0	24.0
Sep-19	16.0	17.0	24.5	17.0	18.0
Oct-03	12.5	12.5	19.0	13.0	13.5
Oct-16	16.0	16.0	19.0	18.0	17.0
Nov-07	6.0	6.0	9.5	6.0	6.5
Nov-20	1.0	1.5	2.0	2.0	1.5
Dec-04	0.0	0.0	3.0	0.0	0.0
Dec-17	0.0	0.0	3.5	0.0	0.0

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling in 1996

Date 1996	ΔT(°C) Upstream River (Sta. 2) vs. Discharge (Sta. 5)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 3)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 4)	Station Output (% Full Power)
Jan-02	1.0	0.5	0.5	99.9
Jan-18	0.0	0.0	0.0	40.6
Feb-01	0.0	0.0	0.0	100.1
Feb-15	2.5	0.5	0.0	96.5
Mar-07	1.5	0.5	0.0	100
Mar-19	1.0	0.5	0.5	75.4
Apr-03	7.5	0.5	0.0	100
Apr-17	11.5	0.5	0.5	99.9
May-01	10.5	0.0	0.5	99.9
May-14	9.0	0.0	0.0	100
Jun-04	5.0	0.0	0.0	99.9
Jun-20	6.5	0.0	0.0	99.9
Jul-02	3.0	0.0	-0.5	99.9
Jul-16	3.0	0.0	-0.5	99.8
Aug-01	3.5	0.0	0.0	100
Aug-15	2.0	0.5	0.5	100
Sep-03	3.5	0.5	0.5	100
Sep-19	7.5	0.0	1.0	99.4
Oct-03	6.5	0.5	1.0	96.5
Oct-16	3.0	2.0	1.0	0.0
Nov-07	3.5	0.0	0.5	0.0
Nov-20	0.5	0.5	0.0	32.5
Dec-04	3.0	0.0	0.0	99.0
Dec-17	3.5	0.0	0.0	100

Table 4

Turbidity (NTU) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	2	2	880	22	18
Jan-18	6	2	6	6	4
Feb-01	4	4	10	3	5
Feb-15	17	15	19	15	17
Mar-07	5	6	8	8	16
Mar-19	25	24	24	28	25
Apr-03	120	110	470	120	120
Apr-17	30	30	88	30	29
May-01	32	35	84	32	32
May-14	54	60	240	60	58
Jun-04	84	76	260	80	80
Jun-20	91	94	450	94	96
Jul-02	50	61	240	60	54
Jul-16	40	40	80	38	44
Aug-01	33	32	56	31	30
Aug-15	34	32	30	38	30
Sep-03	36	30	52	32	32
Sep-19	24	24	66	26	33
Oct-03	22	24	92	28	28
Oct-16	22	24	19	24	24
Nov-07	18	20	15	19	20
Nov-20	57	48	56	52	48
Dec-04	5.6	6.8	10	6.0	6.4
Dec-17	13	11	11	13	14

Table 5

Total Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	380	390	3400	480	470
Jan-18	340	350	360	350	360
Feb-01	400	400	1400	440	440
Feb-15	320	330	1200	360	340
Mar-07	330	330	720	360	350
Mar-19	330	340	360	360	350
Apr-03	410	430	1200	440	420
Apr-17	370	380	2100	430	400
May-01	360	360	1800	370	390
May-14	440	500	2200	510	500
Jun-04	520	530	1900	540	530
Jun-20	530	490	2400	520	530
Jul-02	480	490	2600	510	510
Jul-16	360	350	1700	360	400
Aug-01	320	320	1700	350	340
Aug-15	320	310	1600	340	340
Sep-03	330	300	1400	350	370
Sep-19	290	300	1600	350	360
Oct-03	310	320	1700	340	370
Oct-16	320	*	290	260	310
Nov-07	390	400	380	400	390
Nov-20	540	530	530	560	500
Dec-04	420	410	1260	450	430
Dec-17	380	380	900	410	400

*Laboratory Accident

Table 6

Dissolved Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

	Sampling Locations				
Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	370	360	600	390	410
Jan-18	340	350	360	350	360
Feb-01	390	380	1300	410	400
Feb-15	300	300	1100	320	300
Mar-07	310	300	680	330	310
Mar-19	280	280	310	300	290
Apr-03	220	220	1100	230	220
Apr-17	300	290	1900	340	320
May-01	260	260	1600	260	270
May-14	300	320	1700	340	370
Jun-04	320	320	1400	310	330
Jun-20	280	270	1800	280	300
Jul-02	330	330	2100	340	350
Jul-16	220	210	1500	220	240
Aug-01	220	210	1500	230	240
Aug-15	200	190	1500	210	220
Sep-03	210	210	1200	240	260
Sep-19	210	210	1300	220	280
Oct-03	240	240	1400	240	280
Oct-16	230	190	240	*	240
Nov-07	350	330	330	340	340
Nov-20	380	350	390	380	370
Dec-04	380	380	1210	420	410
Dec-17	340	340	850	350	340

*Laboratory Accident

Table 7

Suspended Solids (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	1	1	2800	65	36
Jan-18	4	2	4	4	4
Feb-01	1	1	7	3	3
Feb-15	16	15	13	18	22
Mar-07	3	6	5	9	12
Mar-19	50	50	38	60	50
Apr-03	180	190	44	200	180
Apr-17	60	69	140	69	68
May-01	82	86	87	83	82
May-14	130	130	390	130	130
Jun-04	170	170	470	180	180
Jun-20	200	180	620	200	180
Jul-02	120	120	340	130	120
Jul-16	120	120	150	120	130
Aug-01	93	89	96	95	85
Aug-15	110	100	47	110	92
Sep-03	98	78	100	81	92
Sep-19	70	70	150	77	82
Oct-03	66	68	160	74	75
Oct-16	49	60	46	58	63
Nov-07	44	43	28	43	42
Nov-20	150	140	140	160	140
Dec-04	4	6	7	6	5
Dec-17	15	18	6	19	25

Table 8

Dissolved Oxygen (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	11.9	11.9	12.0	12.0	11.8
Jan-18	13.7	13.7	13.6	13.3	13.9
Feb-01	9.6	10.0	9.2	9.8	10.2
Feb-15	12.1	12.4	9.8	12.2	13.2
Mar-07	12.7	12.4	11.5	12.4	12.6
Mar-19	11.3	12.0	12.1	11.8	11.8
Apr-03	12.2	12.3	9.1	11.9	12.6
Apr-17	15.6	15.3	9.2	14.9	15.5
May-01	15.7	16.2	8.6	16.0	16.2
May-14	11.8	11.7	7.9	11.8	11.8
Jun-04	8.9	9.2	6.8	9.2	8.8
Jun-20	8.1	8.1	7.8	8.1	8.0
Jul-02	8.6	8.8	7.1	8.4	7.8
Jul-16	13.6	15.1	6.1	15.1	14.4
Aug-01	11.9	12.4	5.3	12.6	13.5
Aug-15	10.3	10.7	1.7	9.8	11.2
Sep-03	12.6	13.3	4.0	12.9	13.6
Sep-19	14.9	14.4	6.5	14.6	16.3
Oct-03	15.9	15.1	7.7	15.0	16.1
Oct-16	11.8	13.0	9.2	11.1	13.9
Nov-07	12.1	12.4	11.5	12.3	12.5
Nov-20	13.5	13.7	13.8	13.7	13.5
Dec-04	14.5	14.1	9.1	14.5	14.3
Dec-17	14.3	14.3	9.0	14.5	14.4

Table 9

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	5	7	*	5	6
Jan-18	6	7	4	6	7
Feb-01	17	22	*	24	10
Feb-15	12	12	*	11	13
Mar-07	15	15	<1	7	9
Mar-19	6	6	5	4	5
Apr-03	8	5	*	5	5
Apr-17	<1	<1	*	<1	<1
May-01	<1	<1	*	<1	<1
May-14	3	3	*	2	2
Jun-04	2	3	*	3	3
Jun-20	4	4	*	4	4
Jul-02	2	2	*	2	2
Jul-16	<1	<1	*	<1	<1
Aug-01	<1	<1	*	<1	<1
Aug-15	<1	<1	*	<1	<1
Sep-03	<1	<1	*	<1	<1
Sep-19	<1	<1	*	<1	<1
Oct-03	<1	<1	*	<1	<1
Oct-16	1	<1	3	2	2
Nov-07	4	5	4	3	3
Nov-20	4	5	4	5	5
Dec-04	5	5	*	5	7
Dec-17	6	6	7	6	5

*Unable to calculate

Table10

Total Alkalinity (mg/L-CaCO) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	248	240	870	232	232
Jan-18	220	218	222	214	220
Feb-01	242	244	104	252	246
Feb-15	168	176	104	166	172
Mar-07	196	194	272	192	198
Mar-19	190	188	176	180	194
Apr-03	136	132	120	134	130
Apr-17	202	198	106	192	192
May-01	164	164	100	162	166
May-14	184	192	120	188	190
Jun-04	203	202	124	194	190
Jun-20	170	166	106	166	170
Jul-02	194	212	108	204	202
Jul-16	128	128	96	120	126
Aug-01	128	116	80	124	120
Aug-15	110	94	94	96	92
Sep-03	110	120	100	114	112
Sep-19	118	124	142	130	126
Oct-03	118	122	84	120	124
Oct-16	138	136	146	140	140
Nov-07	218	216	218	220	224
Nov-20	212	216	204	212	224
Dec-04	232	234	170	234	230
Dec-17	218	222	178	212	220

Table11

Carbonate Alkalinity (mg/L-CaCO) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

	Sampling Locations				
Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	<1	<1	<1	<1	<1
Jan-18	<1	<1	<1	<1	<1
Feb-01	<1	<1	<1	<1	<1
Feb-15	<1	<1	<1	<1	<1
Mar-07	<1	<1	22	<1	<1
Mar-19	<1	<1	<1	<1	<1
Apr-03	<1	<1	<1	<1	<1
Apr-17	16	14	<1	14	14
May-01	10	10	<1	10	14
May-14	<1	<1	<1	<1	<1
Jun-04	<1	<1	<1	<1	<1
Jun-20	<1	<1	<1	<1	<1
Jul-02	<1	<1	<1	<1	<1
Jul-16	6	10	<1	8	10
Aug-01	8	8	<1	17	10
Aug-15	8	8	<1	8	8
Sep-03	6	10	<1	10	10
Sep-19	12	16	<1	18	16
Oct-03	12	14	<1	12	16
Oct-16	<1	4	<1	<1	<1
Nov-07	<1	<1	<1	<1	<1
Nov-20	<1	<1	<1	<1	<1
Dec-04	<1	<1	<1	<1	<1
Dec-17	<1	<1	<1	<1	<1

Table12

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	8.2	8.0	8.2	8.1	8.0
Jan-18	8.0	8.0	8.2	8.0	8.0
Feb-01	7.6	7.5	8.0	7.5	7.9
Feb-15	7.6	7.6	7.7	7.7	7.6
Mar-07	7.6	7.6	8.4	7.9	7.8
Mar-19	8.1	8.1	8.0	8.1	8.0
Apr-03	7.6	7.8	7.7	7.8	7.8
Apr-17	8.6	8.6	7.8	8.6	8.7
May-01	8.4	8.5	7.8	8.5	8.6
May-14	8.2	8.2	7.8	8.3	8.3
Jun-04	8.2	8.1	7.3	8.2	8.1
Jun-20	7.9	7.9	7.8	8.1	8.0
Jul-02	8.3	8.3	7.9	8.3	8.3
Jul-16	8.7	8.8	7.8	8.9	8.8
Aug-01	8.6	8.7	7.4	8.8	8.9
Aug-15	8.8	8.8	7.1	8.8	9.1
Sep-03	8.5	8.7	7.5	8.7	9.0
Sep-19	8.7	8.9	8.0	9.0	9.1
Oct-03	8.8	8.8	7.7	8.9	8.9
Oct-16	8.3	8.6	7.9	8.1	8.3
Nov-07	8.1	8.1	8.1	8.2	8.2
Nov-20	8.1	8.1	8.1	8.1	8.1
Dec-04	8.1	8.1	7.5	8.1	8.0
Dec-17	8.0	8.0	7.8	8.0	8.1

Table13

Total Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan-02	275	280	360	305	285
Jan-18	250	270	290	360	330
Feb-01	340	380	950	350	400
Feb-15	300	320	780	290	290
Mar-07	280	240	520	260	240
Mar-19	240	230	340	260	240
Apr-03	160	180	700	190	230
Apr-17	260	260	1300	280	320
May-01	240	220	1000	240	240
May-14	245	255	1080	265	255
Jun-04	280	280	950	280	290
Jun-20	240	280	1200	280	270
Jul-02	310	310	1500	300	310
Jul-16	220	260	1000	170	240
Aug-01	280	260	950	230	230
Aug-15	200	180	870	200	200
Sep-03	170	230	810	220	260
Sep-19	180	170	850	170	210
Oct-03	180	190	860	210	220
Oct-16	220	210	230	220	230
Nov-07	280	310	260	320	280
Nov-20	320	340	290	320	340
Dec-04	320	320	800	340	320
Dec-17	300	310	600	310	300

Table14

Calcium Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1996

	Sampling Locations				
Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	165	195	280	190	200
Jan-18	220	170	180	200	150
Feb-01	240	240	580	260	250
Feb-15	160	190	480	180	220
Mar-07	170	180	340	180	180
Mar-19	170	170	150	170	160
Apr-03	120	110	470	120	120
Apr-17	180	180	820	220	220
May-01	140	120	630	150	150
May-14	150	140	670	160	150
Jun-04	200	200	650	200	200
Jun-20	180	200	820	180	200
Jul-02	220	210	960	200	190
Jul-16	120	120	520	120	120
Aug-01	96	92	470	100	92
Aug-15	80	110	480	72	110
Sep-03	76	80	400	88	84
Sep-19	90	75	420	90	90
Oct-03	110	110	480	100	100
Oct-16	96	96	100	100	100
Nov-07	230	200	180	200	200
Nov-20	230	230	200	260	260
Dec-04	210	210	520	220	200
Dec-17	180	200	390	210	190

Table 15

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	0.2	0.2	5.4	0.3	0.3
Jan-18	0.2	0.2	0.2	0.2	0.2
Feb-01	0.3	0.4	1.7	0.4	0.4
Feb-15	0.7	0.7	2.2	0.7	0.7
Mar-07	0.4	0.3	1.7	0.4	0.4
Mar-19	0.3	0.3	0.3	0.3	0.3
Apr-03	0.6	0.6	1.4	0.7	0.7
Apr-17	0.3	0.3	1.4	0.3	0.3
May-01	0.3	0.2	2.0	0.2	0.3
May-14	0.3	0.3	2.8	0.3	0.3
Jun-04	0.5	0.4	2.6	0.4	0.4
Jun-20	0.4	0.4	2.1	0.4	0.4
Jul-02	0.3	0.3	1.7	0.3	0.3
Jul-16	0.2	0.3	1.9	0.2	0.2
Aug-01	0.2	0.1	1.7	0.2	0.2
Aug-15	0.3	0.3	1.1	0.3	0.3
Sep-03	0.2	0.2	1.2	0.3	0.3
Sep-19	0.2	0.2	1.3	0.2	0.3
Oct-03	0.2	0.2	1.4	0.3	0.3
Oct-16	0.2	0.2	0.2	0.2	0.2
Nov-07	0.2	0.2	0.2	0.2	0.2
Nov-20	0.3	0.3	0.3	0.3	0.3
Dec-04	0.1	0.2	1.1	0.2	0.1
Dec-17	0.2	0.2	0.7	0.2	0.2

Table 16

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1996

	Sampling Locations				
Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	0.1	0.2	0.2	0.2	0.2
Jan-18	0.2	0.2	0.2	0.2	0.2
Feb-01	0.3	0.3	0.8	0.3	0.3
Feb-15	0.6	0.6	1.5	0.6	0.6
Mar-07	0.3	0.3	0.9	0.3	0.3
Mar-19	0.2	0.2	0.2	0.2	0.2
Apr-03	0.3	0.3	0.9	0.3	0.3
Apr-17	<0.1	<0.1	0.4	<0.1	<0.1
May-01	<0.1	<0.1	0.5	<0.1	<0.1
May-14	<0.1	<0.1	0.8	<0.1	<0.1
Jun-04	<0.1	<0.1	1.2	<0.1	0.1
Jun-20	0.1	0.1	0.6	0.1	0.1
Jul-02	0.1	0.1	0.6	0.1	0.1
Jul-16	<0.1	<0.1	0.6	<0.1	<0.1
Aug-01	<0.1	<0.1	0.3	<0.1	<0.1
Aug-15	<0.1	<0.1	0.4	<0.1	<0.1
Sep-03	<0.1	<0.1	0.3	<0.1	<0.1
Sep-19	<0.1	<0.1	<0.1	<0.1	<0.1
Oct-03	<0.1	<0.1	0.2	<0.1	<0.1
Oct-16	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-07	0.1	0.1	0.1	0.1	0.1
Nov-20	0.1	0.1	0.1	0.1	0.1
Dec-04	0.1	0.1	0.5	0.1	0.1
Dec-17	0.1	0.1	0.4	0.1	0.1

Table 17

Ammonia (mg/L-N) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

	Sampling Locations				
Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	0.2	0.2	0.7	0.2	0.2
Jan-18	0.3	0.3	0.4	0.3	0.3
Feb-01	0.9	0.9	0.1	0.9	0.9
Feb-15	0.8	0.8	0.2	0.8	0.8
Mar-07	0.5	0.6	<0.1	0.5	0.6
Mar-19	0.4	0.3	0.4	0.3	0.3
Apr-03	0.3	0.3	0.3	0.3	0.3
Apr-17	<0.1	<0.1	<0.1	<0.1	<0.1
May-01	<0.1	<0.1	<0.1	<0.1	<0.1
May-14	<0.1	<0.1	0.2	<0.1	<0.1
Jun-04	<0.1	<0.1	2.9	<0.1	<0.1
Jun-20	<0.1	<0.1	0.1	<0.1	<0.1
Jul-02	<0.1	<0.1	<0.1	<0.1	<0.1
Jul-16	<0.1	<0.1	0.2	<0.1	<0.1
Aug-01	<0.1	<0.1	0.2	<0.1	<0.1
Aug-15	<0.1	<0.1	0.5	<0.1	<0.1
Sep-03	<0.1	<0.1	0.8	<0.1	<0.1
Sep-19	<0.1	<0.1	<0.1	<0.1	<0.1
Oct-03	<0.1	<0.1	0.1	<0.1	<0.1
Oct-16	<0.1	<0.1	0.1	<0.1	<0.1
Nov-07	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-20	0.1	0.1	0.2	0.1	0.1
Dec-04	0.1	0.1	0.1	0.1	0.1
Dec-17	0.1	0.1	0.7	0.1	0.1

Table 18

Nitrate (mg/L-N) Values for the Cedar River
near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	5.1	5.1	5.9	5.3	5.3
Jan-18	5.0	5.0	4.8	4.9	4.9
Feb-01	5.0	5.2	13	5.4	5.2
Feb-15	4.0	4.1	10	4.2	4.1
Mar-07	3.9	3.9	4.6	4.1	4.0
Mar-19	3.1	3.1	5.6	3.2	3.2
Apr-03	4.8	4.9	14	5.1	5.0
Apr-17	2.9	2.9	14	3.1	2.9
May-01	3.3	3.2	14	3.2	3.3
May-14	6.3	6.4	22	6.4	6.4
Jun-04	11	11	19	11	11
Jun-20	11	11	36	11	11
Jul-02	9.9	9.8	42	9.9	10
Jul-16	3.7	3.6	17	3.6	3.8
Aug-01	1.7	1.4	7.7	1.5	1.6
Aug-15	0.4	0.3	1.5	0.3	0.3
Sep-03	0.9	0.8	3.8	0.8	0.8
Sep-19	0.5	0.4	2.7	0.4	0.5
Oct-03	0.9	0.8	4.0	0.9	1.0
Oct-16	1.0	1.0	1.0	0.9	1.1
Nov-07	5.2	5.2	4.4	5.2	5.2
Nov-20	7.6	7.8	7.7	7.7	7.6
Dec-04	8.2	8.4	12	8.5	8.2
Dec-17	7.6	7.5	8.4	7.8	7.8

Table 19

Total Iron (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	0.10	0.10	56	1.2	0.87
Jan-18	0.18	0.15	0.18	0.17	0.16
Feb-01	0.11	0.12	0.48	0.14	0.16
Feb-15	0.73	0.71	0.98	0.89	0.94
Mar-07	0.19	0.24	0.57	0.33	0.74
Mar-19	1.3	1.2	1.1	1.2	1.3
Apr-03	6.0	5.9	2.8	6.0	5.9
Apr-17	1.2	0.93	3.4	1.0	1.1
May-01	0.90	0.92	2.8	0.90	0.96
May-14	3.1	3.0	12	2.9	3.8
Jun-04	4.9	4.3	12	4.9	5.1
Jun-20	5.9	5.9	22	5.3	5.8
Jul-02	3.0	3.6	12	3.3	3.5
Jul-16	1.4	1.4	2.8	1.3	2.1
Aug-01	0.80	0.89	1.5	0.94	1.0
Aug-15	1.1	1.1	0.77	0.97	1.0
Sep-03	0.66	0.56	1.5	1.0	0.81
Sep-19	0.31	0.44	1.6	0.41	0.64
Oct-03	0.38	0.40	2.0	0.47	0.50
Oct-16	0.31	0.43	0.49	0.44	0.49
Nov-07	0.94	0.92	0.58	0.88	0.91
Nov-20	2.9	2.8	2.8	3.2	2.4
Dec-04	0.18	0.22	1.0	0.23	0.21
Dec-17	0.72	0.63	0.53	0.65	0.84

Table 20

Biochemical Oxygen Demand (5-day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-02	1	3	24	3	3
Jan-18	1	2	2	2	2
Feb-01	2	<1	2	1	1
Feb-15	7	6	6	6	7
Mar-07	3	3	2	3	3
Mar-19	2	2	2	3	2
Apr-03	8	5	4	5	6
Apr-17	6	7	15	6	7
May-01	11	12	16	12	12
May-14	5	6	16	8	8
Jun-04	4	5	18	4	3
Jun-20	3	3	6	3	3
Jul-02	3	3	8	3	3
Jul-16	13	12	18	13	13
Aug-01	13	13	22	14	15
Aug-15	17	17	18	18	18
Sep-03	14	16	17	14	15
Sep-19	15	16	19	14	16
Oct-03	14	12	35	14	16
Oct-16	17	18	12	13	17
Nov-07	3	2	2	2	2
Nov-20	2	4	4	3	3
Dec-04	2	1	2	2	1
Dec-17	1	1	1	1	1

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	440	370	11,000	440	950
Jan-18	240	150	220	290	300
Feb-01	700	640	200	450	290
Feb-15	690	530	600	850	690
Mar-07	80	82	10	80	27
Mar-19	140	140	170	190	180
Apr-03	340	290	350	270	350
Apr-17	<10	20	40	<10	55
May-01	27	10	73	45	10
May-14	210	330	70	200	170
Jun-04	690	490	6800	420	380
Jun-20	1200	1200	3900	1000	910
Jul-02	300	220	210	310	290
Jul-16	900	30	350	60	130
Aug-01	60	30	9	50	45
Aug-15	50	<10	300	20	70
Sep-03	20	20	100	10	40
Sep-19	<10	10	190	<10	60
Oct-03	<10	20	50	36	20
Oct-16	<10	18	20	20	40
Nov-07	1900	2000	1300	1800	2100
Nov-20	1200	1400	1000	2200	1000
Dec-04	120	70	450	100	64
Dec-17	480	360	10	350	350

Table 22

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1996

Date 1996	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-02	300	210	1600	250	240
Jan-18	170	210	160	110	110
Feb-01	510	370	140	360	310
Feb-15	900	820	470	750	670
Mar-07	<10	27	<10	10	<10
Mar-19	160	55	50	110	120
Apr-03	250	210	180	160	180
Apr-17	20	<10	30	10	27
May-01	<10	10	80	10	20
May-14	130	92	50	110	160
Jun-04	500	490	7500	510	360
Jun-20	840	890	2000	810	980
Jul-02	140	150	190	320	230
Jul-16	20	20	140	<10	40
Aug-01	70	30	45	50	60
Aug-15	55	<10	160	40	30
Sep-03	10	<10	190	10	20
Sep-19	<10	10	200	<10	60
Oct-03	20	27	50	20	40
Oct-16	10	10	30	30	90
Nov-07	2200	2700	2100	1800	1600
Nov-20	1200	1200	1200	1200	2000
Dec-04	120	54	850	73	60
Dec-17	420	360	45	460	440

Table 23

Additional Chemical Analysis-1996

Station	Cl^- (mg/L)	SO_4 (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			Apr-17					
1. Lewis Access	24	38	<20	<10	<10	120	<1	<20
2. Upstream DAEC	25	38	<20	<10	<10	110	<1	<20
3. Downstream DAEC	26	62	<20	<10	<10	120	<1	<20
4. One-half mile below plant	24	48	<20	<10	<10	120	<1	<20
5. Discharge Canal	100	1000	<20	20	<10	330	<1	55
			Jul-02					
1. Lewis Access	22	35	<20	<10	<10	160	<1	20
2. Upstream DAEC	22	36	<20	<10	<10	190	<1	20
3. Downstream DAEC	22	35	<20	<10	<10	180	<1	<20
4. One-half mile below plant	23	36	<20	<10	<10	190	<1	20
5. Discharge Canal	20	1100	<20	30	<10	530	<1	710

Table 24

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, 7/17/96-8/19/96.

Taxon	Lewis Access	U/S DAEC	D/S DAEC	1 mi. below plant	Disc. Canal
Annelida					
Oligochaeta					
Haplotaxida					
Tubificidae					84
Platyhelminthes					
Turbellaria					
Planariidae					
Dugesia sp			6		
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Elmidae					
Dubiraphia sp.			1		
Macronychus sp.			1		
Stenelmis crenata			8		
Stenelmis spp.	4	5			
Diptera					
Athericidae					
Atherix spp.			2		
Chironomidae	900	1012	1680	784	
Simuliidae					
Simulium spp.	2		1		
Empididae			4		
Ephemeroptera (Mayflies)					
Baetidae					
Baetis brunneicolor			1		
Baetis longipalpus	4	21	35	1	
Baetis spp.			1		
Caenidae					
Caenis spp.		1	5	1	
Heptageniidae					
Heptagenia pulla		4			
Stenonema exiguum			2	1	
Stenonema integrum		2	4	1	
Stenonema pulchellum		5			
Stenonema spp.			1	2	
Oligoneuriidae					
Isonychia spp.			15	12	
Tricorythidae					
Tricorythodes spp.			2	4	
Megaloptera					
Corydalidae					
Corydalus cornutus			1		

Table 24 (con't)

Taxon	Lewis Access	U/S DAEC	D/S DAEC	1 mi. below plant	Disc. Canal
Plecoptera (Stoneflies)					
Perlidae					
Acroneuria spp.	2	2	2	1	
Trichoptera (Caddisflies)					
Brachycentridae					
Brachycentrus numrosus			1		
Hydropsychidae					
Cheumatopsyche spp.	2	16	12	28	
Hydropsyche bidens	754	930	1077	268	5
Hydropsyche orris	48	44	75	32	
Hydropsyche simulans	10	10	15	8	
Potamyia flava	218	24	22		
Total Organisms	**1,944**	**2,076**	**2,974**	**1,143**	**89**
No. Organisms/m²	**19,440**	**20,760**	**29,740**	**11,430**	**890**

*DAEC Discharge Canal

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 24 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, 9/19/96-10/3196.

Taxon	Lewis Access	U/S DAEC	D/S DAEC	½ mi. below plant	Disc. Canal
Annelida					
Oligochaeta					
Haplotaxida					
Tubificidae			3		
Platyhelminthes					
Turbellaria					
Planariidae					
Dugesia sp.			1		
Mollusca					
Gatropoda					
Physidae					
Physa sp.			1		
Arthropoda					
Arachnoidea					
Hydracarina			1	1	
Insecta					
Coleoptera (Beetles)		1			
Diptera					
Chironomidae	36	49	41	183	22
Simuliidae					
Simulium spp.		3	3	49	3
Empididae				1	
Hemerodromia spp.	3				
Ephemeroptera (Mayflies)					
Heptageniidae					
Heptagenia spp.	1	3	1	2	
Stenonema tripunctatum		19	33		
Stenonema spp.	4	13	30	56	
Oligoneuriidae					
Isonychia spp.				4	
Tricorythidae					
Tricorythodes spp.			1		
Plecoptera					
Taeniopterygidae					
Taeniopteryx spp.		15	21	38	
Trichoptera (Caddisflies)					
Hydropsychidae					
Cheumatopsyche spp.	1	8	3	12	
Hydropsyche bidens	23	68	115	144	
Hydropsyche orris	18	54	15	28	
Hydropsyche simulans	8	5	10	2	
Potamyia flava	71	48	59	60	
Leptoceridae					
Nectopsyche spp.		1			
Total Organisms	**165**	**287**	**338**	**580**	**25**
No. Organisms/m^2	**1,650**	**2,780**	**3,380**	**5,800**	**250**

*DAEC Discharge Canal

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January-December 1996

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2	0	6	5	0	0	0	0	1	0	7	1
2	3	0	4	0	0	0	0	0	2	0	4	1
3	1	0	4	2	1	1	0	0	1	1	5	0
4	0	0	4	2	0	0	0	0	0	0	0	2
5	2	0	5	7	0	2	0	0	0	0	7	
6	4	0	7	5	0	0	0	0	0	0	4	1
7	0	0	3	4	0	0	0	0	0	0	1	2
8	3	0	5	4	0	0	0	1	0	0	1	1
9	6	37	0	6	0	0	0	0	0	0	4	0
10	1	2	3	13	0	0	0	0	0	0	7	5
11	0	11	5	7	0	0	0	1	0	0	2	2
12	8	15	3	4	0	0	0	0	0	2	7	0
13	7	0	49	3	0	0	0	0	0	0	2	3
14	6	5	45	1	1	1	0	0	0	0	4	1
15	0	7	32	2	0						2	3
16	3	5	23	1	0	0	0	0	0	0	7	5
17	2	0	22	0	1	1	0	1	0	0	3	15
18	0	0	12	0	1	0	0	0	0	0	6	1
19	0	5	11	1	0	2	1	0	0	0	4	3
20	1	8	22	0	0	2	0	0	0	0	3	2
21	0	4	15	0	0	0	0	0	0	0	2	3
22	0	0	17	2	0	0	0	0	0	0	3	0
23	0	3	-	0	0	0	0	0	0	0	2	12
24	0	5	-	18	0	1	0	0	0	0	1	0
25	0	27	12	1	0	0	0	1	0	0	*	1
26	*	19	20	1	0	0	0	0	0	1	*	0
27	0	9	20	2	0	0	0	0	0	0	0	10
28	0	0	12	2	0	0	0	3	0	1	3	0
29	0	4	6	0	0	0	0	*	0	0	2	3
30	0	-	8	1	1	0	0	*	0	0	2	1
31	0	-	10	-	0	-	0	0	-	0	-	0
Total	47	166	385	94	5	10	1	7	4	5	95	78
Annual Total	897											

*No Data

Table 26

Comparison of Average Values for Several Parameters at Upstream, Downstream, and Discharge Canal Locations at the Duane Arnold Energy Center During Periods Of Station Operation-1996

Parameters	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Downstream (Sta.4)
Temperature (°C)	10.5	14.7	10.7 (102%)
Dissolved Solids (mg/L)	287	1192	308 (107%)
Total Hardness (mg/L)	254	818	274 (108%)
Total Phosphate (mg/L)	0.30	1.64	0.32 (107%)
Nitrate (mg/L as N)	4.9	12.3	4.9 (100%)
Iron (mg/L)**	1.69	4.02	1.85 (109%)

*Percent of upstream level ()
**January 2 data deleted

Table 27

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1996

Year	Mean flow** (cfs)	Turbidity (NTU)	Total PO (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,375	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	0.30	1.5	10.3	224
1990	5,061	33	0.29	0.20	7.3	4.8	283
1991	8,085	65	0.38	0.20	7.9	4.3	268
1992	5,717	49	0.31	0.16	6.4	5.5	261
1993	15,900	44	0.27	0.16	6.2	2.3	276
1994	4,701	34	0.28	0.22	5.1	5.3	269
1995	4,384	31	0.21	0.17	5.5	4.0	275
1996	3,200	34	0.29	0.21	4.7	7.0	254

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Energy Center* 1972-1996

Year	Mean Flow (cfs)	Cumulative** Runoff (in)	Turbidity	Relative Loading Values Total PO	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74
1992	5,717	10.92	535	3.4	1.7	70	61
1993	15,900	32.39	1425	8.8	5.2	201	74
1994	4,701	10.45	355	2.9	2.3	53	55
1995	4,384	9.23	286	1.9	1.6	51	37
1996	3,200	6.67	227	1.9	1.4	31	47

*Data from Lewis Access location (Station 1)

**Data from U.S. Geological Survey Cedar Rapids gauging station